The Economist explains

# What is AMOC, the heat-distributing Atlantic current?

A slowdown in the Atlantic Meridional Overturning Circulation would have disastrous effects

IMAGE: GETTY IMAGES

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Ask a climate scientist about possible "tipping points" and you are likely to hear about AMOC. The Atlantic Meridional Overturning Circulation is a stream of water which, as it flows from the southern to the northern (hence "meridional") part of the Atlantic, grows cooler and saltier. Eventually it sinks to the ocean floor, 3km down, and flows back (hence "overturning") across the abyssal plain. Mounting evidence suggests that the system that helps distribute heat around the world is weakening. Why do scientists find this so worrying?

AMOC is something of a poster child for tipping points, which are notional thresholds beyond which systems that have been responding gradually and incrementally to global warming undergo sudden and dramatic changes. One reason for this is its sheer power and the scope of its influence. The rate at which it transfers heat towards the pole—about one petawatt, or 1,000 terawatts, roughly 60 times the rate at which humans produce energy by burning fossil fuels in factories, furnaces, power stations, cars, aircraft and everything else—accounts for about a quarter of all the northward flow of heat from the tropics. At least half of the water that gets into the ocean depths does so in the North Atlantic.

Another reason is that its tipping-point nature is not open to question. Theory, modelling and reconstructions of prehistoric climate all support the idea that AMOC is "bistable". Rather than just gradually getting stronger or weaker, it can go suddenly from "on" to "off" if pushed too far, and does so in a way that makes it very hard to flip it back on again. It was one of the first such instabilities clearly demonstrated in the climate system. And on top of all that there has long been good reason to think that global warming may be pushing that switch. On July 25th a paper published in *Nature Communications* suggested that the change of state could come about by the middle of this century.

The overturning circulation is often confused with the Gulf Stream, which runs across the Atlantic in the same direction, but there is a crucial difference. The Gulf Stream is pushed along by winds which will persist whatever the climate. The waters of AMOC are drawn forward by the sinking of those ahead of them, as if on a conveyor-belt. If the near-surface part of the circulation stops getting salty (and thus dense) enough to sink, the circulation stops, and warm water stays where it is. The amount of heat moving north falls by more than half.

That would have dire effects. Northern Europe would get both colder—bringing worse winters, more powerful storms inland and shorter growing seasons—and drier, making summers more prone to drought. The impact on agriculture would be far greater than that caused by warming alone, hitting poorer countries hardest. By slowing the transfer of heat to the north, such a state would push the "intertropical convergence zone"—the tropical belt where the weather systems of the two hemispheres meet—towards the south. This could lead to a drying out of the southern edge of the Sahara, and a spectacular desiccation of Central and northern South America, as well as other impacts around the globe.

Wallace Broecker, an American oceanographer whose work in the 1980s first demonstrated the on-off nature of AMOC, saw it as a powerful cautionary tale for how suddenly climate change could come. "The climate is an angry beast," he used to say, "and we are poking it with a sharp stick."

The stick in question is a freshening of the water in the North Atlantic caused by increased rainfall and melting ice, both expected results of warming caused by greenhouse gases. The climate models used by the Intergovernmental Panel on Climate Change (IPCC) show this leading to a weakening of the circulation over this century, an outcome the panel sees as "very likely" (with a probability above 90%). But they do not show it weakening enough to cross the tipping point and shut itself down.

The lack of a shutdown in the models was one of the reasons that, up until the 2010s, the IPCC tended to be pretty sanguine about the risks. In 2019 it said a shutdown this century was "very unlikely" in 2019. Its most recent assessment, published in 2021, saw the panel recognise that new data and new modelling made it harder to say anything that certain. In some ways that felt almost like good news: it lowered its level of confidence in the idea that measurements made since the 19th century showed a slowdown to already be under way. In other ways it was alarming. This time the conclusion that there would be no shutdown this century was offered with only "medium" confidence. One factor in that reassessment was an acceptance that climate models are systematically biased towards stability in this particular respect. Another was that they did not take specific account of the effects of melting Greenland ice.

In light of this uncertainty, some scientists are seeking out early warnings of a shutdown. The paper that Peter and Susanne Ditlevsen, both at the University of Copenhagen, published in *Nature Communications* in July was such an attempt, using statistics to spot subtle signs of an approaching tipping point. Direct measurements of the strength of AMOC go back only as far as the deployment of the sensor system called RAPID in 2004. So instead the researchers studied a "fingerprint" of the circulation based on surface temperatures in a particular patch of the North Atlantic since the 1870s. Their statistical analysis suggested a 95% chance of a shutdown in the window from 2025 to 2095.

Though the authors tried to limit the number of assumptions they made, some could still prove erroneous. One such is that AMOC's potential tipping point would lead to its total collapse; it might instead shift into some other mode, perhaps one where the location of the sinking moves elsewhere but the flow continues. In that sense AMOC is similar to other systems where tipping points have been diagnosed, such as the conversion of the Amazon into savannah or the collapse of the West Antarctic ice sheet. All such angry beasts need further study to better characterise their behaviour. But no one should expect those studies to be conclusive—or expect any guarantee of calm until the poking with sharp sticks subsides. ■

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